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## BOTANICAL GAZETTE

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## THE PHALLOIDEÆ OF THE UNITED STATES.

## III. ON THE PHYSIOLOGY OF ELONGATION OF THE RECEPTACULUM.

EDWARD A. BURT.

DURING the greater part of its existence, the fructification of a fungus of this strange family is a compact egg-shaped body, the outer part consisting of a thick and highly gelatinous peridial wall, and the inner portion of the receptaculum and spore-mass. This stage of existence of the fructification is usually subterranean or semi-subterranean. As it nears the stage in which elongation sets in, the rapid growth of the receptaculum in its limited space in the peridium throws the chamber-walls of the receptaculum and often, as in *Mutinus caninus*, the wall of the stipe as a whole into complicated folds. When the spores are mature, elongation of the receptaculum occurs by processes to be considered in the present paper, the folds of its walls straighten, and the apex of the receptaculum is pushed outward and upward through the investing peridial wall, irregularly rupturing the latter, which remains, however, connected with the receptaculum at the base and forms a loose bag, the volva, about its lower end. Through elongation of the receptaculum, the spore-mass is carried upward to a position more advantageous for the dispersal of the spores; this seems to be the end attained.

The straightening out of the folds in the chamber-walls of *Phallus caninus* and of *Phallus impudicus* was stated by De Bary to be due, in his opinion, to the inflation of the chambers by the formation of a gas within them.<sup>1</sup> This idea found its way into the text-books.<sup>2</sup>

Such an explanation of the phenomenon has been objected to by Ed. Fischer.<sup>3</sup> He points out that the chambers of the receptaculum are not surrounded by air-tight walls; that all the chambers are open on one side in some species which he has studied; and that there is no visible indication of inflation of the chambers during elongation in other cases. On these grounds he concludes that the walls are not passive in their straightening out, as De Bary's explanation necessitated. That they are the active agents he deduces from the forms of the cells of pseudoparenchyma at the ends of the folds, and from their changes in form as the folds straighten. He gives figures showing that at the inner angle of the fold the cells are wedge-shaped as if by compression, while on the periphery of the fold they are elongated and thin as though stretched there. In his experiments of placing such folds in certain aqueous solutions of slight density, the turgescence of the cells increased by absorption of the liquid, they became more nearly spherical, and the effect of such change of form both at the inner angle of the fold and at its periphery must have been to straighten the fold.

Two years before the publication of Fischer's paper, Errera came to the conclusion incidentally in his work *Sur le Glycogene chez les Basidiomycetes*<sup>4</sup> that elongation of the receptaculum in *Phallus impudicus* results from a true process of growth and not from mere turgescence by the simple absorption of water. A

<sup>1</sup> Zur Morphologie der Phalloideen. Beitrage z. Morph. u. Physiol. der Pilze, Abhandl. d. Senkenb. Naturf.-Ges. 5: 202, 207. 1864.

<sup>2</sup> (a) De Bary, Comp. Morph. of the Fungi, etc., Eng. trans. 323.

(b) Sachs, Text-book of Botany, Eng. trans. 341.

<sup>3</sup> Bemerk. über d. Streckungsvorgang d. Phalloideenreceptaculums, Mittheil. d. naturf. Ges. in Bern, 142. 1887.

<sup>4</sup> Mem. de l'Acad. roy. de Belgique 37 (p. 52 of reprint). 1885.

more detailed reference to his views will be given toward the close of my paper.

The material for numbers 1-5 of the following experiments was collected early in October, 1894, on a grassy slope at Fresh Pond, Cambridge, Mass., a locality to which I was directed by Dr. Thaxter. I am indebted to Mr. A. Piper, a student of Middlebury College, for assistance in procuring the supply with which the investigation has recently been completed. Full grown and apparently mature "eggs" of the species *Dictyophora duplicata* (Bosc) were used. They were collected from time to time just before rains, and were kept in moist paper in a paste-board box until elongation of the receptaculum was beginning. This was shown by the beginning of rupture of the volva, usually at the apex. Occasionally, however, the rupture occurs so that a portion of the volva is carried upward on the apex of the pileus. When at this stage of development, the plants were then used as indicated below.

*Experiment 1.*—On October 4, an egg collected October 2 was divided longitudinally into quarters. One of these quarters was put in water, and the other three in aqueous solutions of sugar of 1, 5 and 20 per cent. strength, respectively. The rates of elongation are determined from the respective lengths of the quarters as noted at the hours stated below:

Time		In water	In 1 per cent. sugar sol.	In 5 per cent. sugar sol.	In 20 per cent. sugar sol.
11:00 A. M.	- -	56 <sup>mm</sup>	56 <sup>mm</sup>	56 <sup>mm</sup>	56 <sup>mm</sup>
1:15 P. M.	- -	94	90	66	62
4:45 P. M.	- -	110	106	94	80
8:25 A. M. of next day	114		110	96	83

These results agree with those obtained by Ed. Fischer with *I. impudicus* in various solutions, and they indicate, as he has asserted, that elongation is most rapid in water and in very dilute aqueous solutions, which would be most readily absorbed by the cells of pseudoparenchyma.

Elongation of the receptaculum of these plants is most likely to occur during rainy weather or shortly after rains. This

is the popular belief, with which my observations agree. It suggests the query, is an abundant supply of water needed for elongation of the receptaculum? The following experiment bears on this point:

*Experiment 2.*—On October 22, an egg collected October 9 was divided longitudinally into halves. One of these halves was placed in a dish of water; the other was placed under a bell jar in a moist atmosphere and was supported on slings in a piece of apparatus devised to avoid the resistance to elongation which would have resulted had this half been allowed to rest on the plane surface of a solid.

The supporting apparatus consisted of a horizontal base—a block of wood—into which a heavy wire was inserted from above. This wire extended upward for a distance of 10 to 15<sup>cm</sup> and then bent outward and downward, forming a vertical pillar with a supporting arm. To the free end of the arm was then firmly attached the middle of a horizontal rod, the rod being thus held at a suitable distance above the base of the apparatus and in such a position that its ends were equally distant from any point in the supporting column.

The portion of the receptaculum used in the experiment was suspended in a horizontal position below the horizontal bar by two slings, or loops, made of twine. The receptaculum was supported by slipping its opposite ends through their respective slings, which were movable on the horizontal bar. In all the experiments in which this apparatus was used, the slings were adjusted on the bar at short intervals of time so that appreciable resistance should not be offered to the elongation, and also so that the weight of the receptaculum might not exert a pull favoring elongation.

The results of the experiment were as follows:

Time		Length in water	Length in air
10:15 A.M.	- - - -	47 <sup>mm</sup>	47 <sup>mm</sup>
11:40 A.M.	- - - -	53	48
1:50 P.M.	- - - -	120	57
4:45 P.M.	- - - -	122	92
11:30 A.M. of next day	- -	122	100

In 3 hrs. 35 min. the half in water made an amount of elongation 20<sup>mm</sup> greater than that made by the half in moist air during 25 hrs. 15 min. The experiment seems to indicate that the rapidity of elongation is favored by an abundant supply of water, but that any very appreciable amount in addition to that already contained in the egg is not, perhaps, absolutely necessary. This experiment was made with the last egg available. The same conclusion, however, had been rendered probable by earlier experiments in which more resistance to its elongation was met with by the half of the egg in the moist atmosphere.

A very large part of the substance of the egg is comprised in the volva itself, the greater portion of which is a thick middle layer, very gelatinous, and containing a large amount of moisture. As already shown, the differentiation of the volva is one of the earliest processes in the development of the egg.<sup>5</sup> At the time of beginning of differentiation of the basidia in *Mutinus caninus*, the middle layer of the volva has already undergone gelatinous modification, and has attained a thickness of about one-third of the diameter of the egg, and has come to inclose the tissue of the future receptaculum and gleba at the top and sides—everywhere except at the very base of the egg where the vegetative mycelium of the fungus is in communication with the more central structures.<sup>6</sup> This relation of the volva to the inner parts is retained through all the later development of the egg until the spores are mature and elongation of the receptaculum occurs. What is the function of the volva? Is it protection? Perhaps such varying external conditions as a hot, dry atmosphere or a flooded condition of the soil during heavy storms are prevented by the thick, gelatinous layer full of moisture from exerting a too direct and injurious effect on the inclosed developing gleba and receptaculum. In staining young eggs for sectioning in my studies of several species of Phalloideæ, I find that aqueous stains do not penetrate through the volva so as to give a good stain to the gleba and receptaculum

<sup>5</sup> BOT. GAZ. 22 : 276. fig. 4. 1896.

<sup>6</sup> Ann. of Bot. 10 : 352. fig. 5. 1896.

in eggs having the gelatinous layer fully developed. It is necessary to use alcoholic stains. Or, by reason of its slippery middle layer, the volva may give a glancing effect to blows by falling or other objects. Injury to eggs in digging them is not likely to extend beyond the middle layer, and such eggs go through the process of elongation of the receptaculum in an apparently normal manner. Or the volva may contain some substance unpalatable to insects and other animals, and so protect the eggs from being eaten. I have never collected one showing injury of this kind.

On the other hand, is the volva a structure in which water and, perhaps, plastic substances are accumulated as a reserve for use in elongation of the receptaculum? Or may the function of water storage be combined with the earlier one of protection? The following experiments were made to determine whether elongation of the receptaculum is dependent on water or other substance which may be received from the volva during the process of elongation:

*Experiment 3.*—On October 9, an egg collected October 2 was divided longitudinally into halves. The volva was carefully cut away from one of the halves, care being taken not to injure the base of the stipe. Each half was supported in the apparatus described in *Experiment 2*, and both halves were kept under the same bell jar in an atmosphere kept moist by a strip of damp paper. Rupture of the volva and elongation of the receptaculum began early in the morning, but the apparatus was not ready for use until 10:30 A.M., at which time the partially elongated plant measured about 11 cm in length.

Time	Length of half with volva	Length of half with volva removed
10:30 A.M. - - - -	111 <sup>mm</sup>	114 <sup>mm</sup>
12:00 M. - - - -	116	120
5:00 P.M. - - - -	118	124

*Experiment 4.*—On October 9, a very fine plant, partially elongated, was collected at 4:00 P.M. It was taken to the laboratory at once and divided longitudinally into halves. The

volva was carefully cut away from one of the halves and they were both placed in the supporting apparatus already described. They were covered by a bell jar, but no moist paper was placed under the jar.

Time		Length of half with volva	Length of half with volva removed
5 : 00 P.M.	- - - -	117 <sup>mm</sup>	116 <sup>mm</sup>
7 : 30 A.M. of next day	-	157	151

*Experiment 5.*—On October 10, an egg collected October 9 was divided longitudinally. Elongation was just beginning; the outer layer of the volva was ruptured but the innermost was still intact. It was necessary to loosen the volva from the surface of the gleba and the stipe. The volva was carefully cut away from about the base of one of the halves and they were then placed in the supporting apparatus under a bell jar. No moist paper was placed under the jar.

Time		Length of half with volva	Length of half with volva removed
9 : 15 A.M.	- - - -	46 <sup>mm</sup>	46 <sup>mm</sup>
12 : 45 P.M.	- - - -	82	81

It seems safe to conclude from *Experiments 3-5* that elongation of the receptaculum does not result from any contribution made by the volva during the process. One must look to the receptaculum itself and to the tissues lying next to its walls for the causes producing it.

The receptaculum walls in this stage consist of pseudo-parenchyma so swollen as to show but little trace of its hyphal origin; the chambers contain a tissue highly gelatinous but still showing its hyphal character. The tissue originally occupying the main central cavity of the stipe has the condition of a glairy mass which becomes still more fluid as elongation progresses.

Microscopic examination of one of the folds of the wall just at the beginning of elongation shows that the cells are slightly wedge-shaped at the inner angle of the fold as though compressed, while on the outer surface of the fold they are somewhat flattened as though stretched out there. The cell-like



bodies which are not in the angles of the folds have a more spherical form in general. In a fully elongated stipe the cell-like bodies of pseudoparenchyma are more spherical or ovoid throughout in general, although somewhat irregular.

These facts may indicate, as Ed. Fischer claims,<sup>7</sup> that the straightening of the folds is due to the simple absorption of liquid by the pseudoparenchyma. His theory of elongation of the receptaculum accounts for the increased rapidity of elongation when the receptaculum is immersed in water, as in some of my experiments. It is also favored by the rapid elongation in suitable liquids of slight density, as Fischer has observed. It is not rendered improbable by the occurrence of elongation in an atmosphere containing but little moisture, even though no water supply is being brought up into the plant by the mycelium; for the pseudoparenchymatous walls are found to be constantly moist during elongation, such moisture coming from adjacent gelatinous tissues presumably.

I believe that we may conclude that the straightening out of the folds in elongation is due, in some degree at least, to the change in form—becoming more nearly spherical—of the pseudoparenchyma at the inner angle and the periphery of the folds. But is this change of form due merely to increased turgidity of the pseudoparenchyma by simple absorption of water? May there not be a process of growth going on, as a result of which the change of form occurs?

In his researches on glycogen in Basidiomycetes, Errera<sup>8</sup> gave especial attention to its occurrence in *Ithyphallus impudicus*, and found that in the various stages of that plant the glycogen was most abundant in those parts in which active growth was about to take place. He regards glycogen as a food substance accumulated for use in future growth, and finds that it disappears in the degree that such growth progresses. He found glycogen very abundant in the walls and chambers of the stipe just before elongation began, but it gradually disappeared during elongation, and was wholly lacking except at the base of the

<sup>7</sup> *Loc. cit.*

<sup>8</sup> *Loc. cit.*

stipe when elongation was completed. From this he concludes that elongation of the receptaculum is the result of true growth of the pseudoparenchyma, water being used in the process as it is in other growth.

While Errera's treatment of this problem is very suggestive and his explanation very probable, so also is that by simple absorption of water. It has seemed to me that if it can be shown that there is a decidedly general increase in size of the cells of pseudoparenchyma during elongation, the growth theory will be the truer one. If, however, the increase is confined to the pseudoparenchyma in the angles of the folds, the theory of turgescence must be the more correct.

The necessary data for the determination of this point have been obtained by the microscopic measurement of the individual cells of pseudoparenchyma making up the wall in various parts of the stipe. Eggs just beginning elongation or plants partially elongated were divided longitudinally into halves. Thin radial longitudinal sections were then cut free-hand with a razor from the wall of the stipe of one of the halves. After placing the sections in a drop of water, the measurements were immediately noted of the individual cells in a strip extending across the partition wall.

The part of the receptaculum called the stipe or stem in these plants is a hollow cylindrical body with a wall of chambered structure. The chambers are separated from one another by pseudoparenchymatous partition walls 150–300 $\mu$  thick. Measurements were taken of the pseudoparenchyma in longitudinal partition walls next to the main central cavity of the stipe, at the outer surface of the stipe, between the chambers in the interior of the stipe-wall, at the angles of the folds and at points midway between the angles, and also in transverse partition walls.

The other half of the egg, or partially elongated plant, was kept in the supporting apparatus in a moist atmosphere until the completion of the elongation. Longitudinal radial sections of the stipe-wall were cut, and the pseudoparenchyma then measured at points in the partition walls corresponding to the points

of measurement in the first half. Measurements were made of rather a broad strip across the partition wall to avoid error in the computations through very large or very small cells occasionally found. The individual cells in such a strip were carefully measured by the usual method of measuring spores of fungi, an eyepiece micrometer being employed in the work. The measurements are given in detail at the close of this paper in *Exps. 6-9*, where the several sets of measurements of corresponding parts of the two halves of each specimen are arranged in parallel columns for convenience of comparison. The general results of these experiments are as follows:

In *Exp. 6* the measurements were made on half of a stipe just beginning elongation and on the other half after its completion. The averages of the diameters in the several sets of measurements of the unelongated half vary from  $26.7\mu$  to  $35.3\mu$ , with a general average of  $30.5\mu$  computed on all the measurements. The corresponding averages of the other half after its elongation vary from  $32\mu$  to  $40.5\mu$ , with a general average of  $37.1\mu$  based on all the measurements. These results give an average increase of 22 per cent. in length of diameter of the cells of pseudoparenchyma during elongation of the receptaculum.

*Exp. 7* was made with a fine large plant having its receptaculum already partially elongated. The averages of the sets of measurements of pseudoparenchyma from the partially elongated receptaculum vary from  $28.5\mu$  to  $37.2\mu$  with a general average of  $31.3\mu$  based on all the measurements. The corresponding averages of the other half, after the completion of its elongation, vary from  $36.6\mu$  to  $39\mu$  with a general average of  $37.9\mu$  computed from all the measurements. These results show an increase of 21 per cent. in length of diameter of the cells of pseudoparenchyma during the completion of elongation of the receptaculum.

In *Exp. 8*, also made with a plant partially elongated at the beginning of the experiment, the average lengths of diameter of the pseudoparenchyma vary in the partially elongated half from  $25.5\mu$  to  $32.2\mu$  with an average of  $28.5\mu$  determined from all the

measurements. After completion of elongation the corresponding averages vary from  $27.2\mu$  to  $34.2\mu$ , with a general average of  $31.2\mu$  computed on all the measurements. The increase in length of diameter of the cells of pseudoparenchyma was therefore about  $9\frac{1}{2}$  per cent. in the completion of elongation of the receptaculum.

Comparison of the results of *Exp. 6* with those of *Exps. 7* and *8* indicates a gradual increase in the size of the cells of pseudoparenchyma during the whole course of elongation of the receptaculum. The purpose for which these measurements were made is to decide, however, whether the cells of pseudoparenchyma at or after the close of elongation of the receptaculum are larger in the same plant than at the beginning, or before the completion of the process. In *Exps. 6-8*, comparison with each other of the sets of measurements of corresponding parts of the stipe-wall for the two periods covered by the experiments shows a marked increase in the size of the cells of pseudoparenchyma by the close of elongation. The increase is not confined to the pseudoparenchyma at the angles of the folds, but is approximately uniform for each part of the same plant, not differing much from the percentage of increase for that plant as computed from all the measurements. In *Exp. 6* the increase of 22 per cent. in the average length of diameter of a cell of pseudoparenchyma gives an increase of 81 per cent. in the volume of the cell. In other words, each cell of pseudoparenchyma becomes nearly twice as large by the close of elongation of the receptaculum as it was at the beginning of that process.

Such a general and great increase in the size of each cell of pseudoparenchyma in every part of the stipe must find its explanation in conditions to which all the cells are alike subjected. As the reserves of glycogen disappear from the cells during the course of elongation, we must conclude that the increase in size of the cells of pseudoparenchyma results from their rapid growth at the expense of the glycogen accumulated in and about the receptaculum, and that such water as is used in the process is most probably used as in other cases of growth. The bursting

forth of the receptaculum from the volva and the straightening out of its folded walls in elongation are due, therefore, to a true process of growth of the pseudoparenchyma, during which the cells of pseudoparenchyma at the angles of the folds grow somewhat more spherical, however, and so become to some extent presumably active agents in the process of elongation.

To one not aware of the vitality of these plants, the question may arise as to whether the longitudinal division of the receptaculum into halves may not have injured the plants to such a degree as to invalidate my conclusions. The elongation is perhaps less rapid when the receptaculum has been so divided, but it seems to become complete. The cells of pseudoparenchyma in such cases attain the full dimensions observed in the pseudoparenchyma of a receptaculum from eggs of the same size and apparent vigor, in which elongation has occurred without division of the receptaculum having been made. Under *Exp. 9* are grouped sets of measurements of the pseudoparenchyma in the receptaculum of a vigorous plant whose elongation was normal and was completed before any incision was made into the stipe. The averages of the lengths of diameter of the pseudoparenchyma vary from  $37.7\mu$  to  $38.6\mu$  in this case. In *Exps. 6* and *7* the average diameters of the pseudoparenchyma in the halved receptacula at the completion of elongation were respectively  $37.2\mu$  and  $37.9\mu$ . These three sets of averages agree well; the plants on which they are based were strong plants of about the same size. The specimen used in *Exp. 8* was smaller and slenderer than the others and its pseudoparenchyma cells were also smaller; their average diameter is not probably comparable with those of the specimens used in the other experiments.

The conclusions reached may be summarized as follows:

1. While the rapidity of elongation is favored by an abundant supply of water, still any very appreciable amount in addition to that already contained in the egg is not absolutely necessary.

2. Elongation of the receptaculum is not dependent on any contribution of water or other substance from the volva during

the progress of elongation. The function of the volva is more probably one of protection of the parts it incloses in the egg-stage.

3. During the progress of elongation and coincident with the disappearance of the abundant store of glycogen found by Errera in and about the receptaculum, there is a very rapid and general growth in size of the cells of pseudoparenchyma constituting its walls. The bursting forth of the receptaculum from the volva and the straightening of its folded walls are due to such process of growth of the pseudoparenchyma, during which the cells at the angles of the folds grow somewhat more spherical and so become to some extent presumably active agents in the process of elongation.

ACCOUNT OF EXPERIMENTS 6-9, WITH MEASUREMENTS OF PSEUDOPARENCHYMA.

NOTE.—In the tabulated lists of measurements made in these experiments both the long and short diameters of subspherical or ellipsoidal cells are given. The measurement first given in such cases is in a general direction transversely across the partition wall. For each of such cells one-half the sum of its long and short diameters has been taken as the approximately average diameter for use in computing the general averages. This average diameter is given in parenthesis.

The side of a wall forming a part of the outer surface of the stipe is marked (*a*); the side forming a part of the surface of the main central cavity of the stipe is marked (*c*).

*Experiment 6.*—A strong egg just beginning elongation was divided longitudinally into halves at 3:00 P.M., October 8. Longitudinal radial sections were cut free-hand from the wall of the stipe of one of the halves. These sections were placed in a drop of water on a slide and measurements were immediately made of the cells of pseudoparenchyma in strips across the partition walls which make up the wall of the stipe. These measurements are given in the column on the left below. The other half of the egg was suspended in the supporting apparatus in a

moist atmosphere until after the completion of elongation. On October 10 at 9:00 A.M., sections were cut from it and measurements of their pseudoparenchyma were made as in the case of the first half. These measurements are given in the column on the right.

Before elongation of the receptaculum.		After completion of elongation.	
	$\mu$		$\mu$
	28		48 x 40 (44) <sup>c</sup>
	36		36 x 40 (38)
	36		36 x 44 (40)
	28		40
Longitudinal wall,	32	Longitudinal wall	40
	28	next to central cavity of stipe.	32 x 40 (36)
	28		40 x 28 (34)
	24 x 32 (28)		40 x 32 (36)
Average, -	30.5		40 x 28 (34)
			30
			48 x 30 (39)
		Average, -	37.4
	28 <sup>c</sup>		40 <sup>c</sup>
	24		36 x 52 (44)
	30 x 44 (37)	Longitudinal wall	40 x 52 (46)
Longitudinal wall	28	220 $\mu$ thick next to	44 x 40 (42)
next to central cavity	40	central cavity of	44
of stipe.	60 x 52 (56)	stipe.	48 x 34 (41)
Average, -	35.5		40 x 38 (39)
			28
		Average, -	40.5
	36		28
	28		52
Longitudinal wall	32		52
in interior of stipe	20		32
wall.	32 x 28 (30)		28
	32		44 x 24 (34)
Average, -	29.7		40
			40
		Longitudinal wall	36 x 32 (34)
		360 $\mu$ thick in interior of stipe wall.	32 x 48 (40)
			32 x 40 (36)
			40 x 36 (38)

Before elongation of the receptaculum.		After completion of elongation.	
	$\mu$		$\mu$
			32 x 44 (38)
			40
			36 x 48 (42)
			30 x 40 (35)
			40
			32
			20
		Average, -	36.9
			32
			26
			56 x 40 (48)
		Longitudinal wall	40 x 48 (44)
		220 $\mu$ thick in outer	32
		surface of stipe.	48
			40
			44 x 60 (52)
			30
			28 <i>a</i>
		Average, -	38.8
	24		36
Transverse parti-	32	Transverse parti-	36
tion wall in interior of	24	tion wall in interior	32
stipe wall.	24	of stipe wall.	24
	28		36
	28		28
Average, -	26.7	Average, -	32
			28
			32
			36
		Transverse parti-	28
		tion wall.	36 x 44 (40)
			44
			44
			32
		Average, -	35.5

The measurements of pseudoparenchyma before elongation give 30.5 $\mu$  as the average length of diameter of the cells in that



stage. After completion of the elongation, the corresponding average length is  $37.1\mu$ . These averages show an increase of 22 per cent. in length of diameter of the cells of pseudoparenchyma during elongation of the receptaculum.

*Experiment 7.*—On October 14, an egg just beginning elongation at 1:00 P.M. had partially elongated to the length of  $83^{\text{mm}}$  at 2:30 P.M. The plant was then split longitudinally into halves. Sections were cut from the stipe of one of these halves, and measurements of its pseudoparenchyma were taken as in *Experiment 6*. The measurements are given in the column on the left below. The other half was suspended in the supporting apparatus in a moist atmosphere and had completed its elongation at 4:00 P.M., October 15. It then measured  $113^{\text{mm}}$  in length. Sections were cut from its stipe; the measurements of their pseudoparenchyma are given below in the column on the right.

Before completion of elongation.		After completion of elongation.	
	$\mu$		$\mu$
	20 c		28 c
	22		36
	52 x 40 (46)		48 x 40 (44)
Longitudinal wall	24	Longitudinal wall	32
220 $\mu$ thick, next to	28	240 $\mu$ thick, next to	44
central cavity of stipe	40 x 28 (34)	central cavity of	48
and midway between	32	stipe and midway	44 x 28 (36)
angles.	40 x 56 (48)	between angles.	36 x 34 (35)
	28	Average, -	37.9
	20		
	28		
Average, -	30		
	26 x 40 (33) c		48 x 40 (44) c
	44 x 36 (40)		40 x 32 (36)
Longitudinal wall	40	Longitudinal wall	44 x 32 (38)
240 $\mu$ thick, next to	32	240 $\mu$ thick, next to	56 x 64 (60)
central cavity of stipe	44	central cavity of	36
and near cross wall.	32	stipe.	36 x 48 (42)
	52 x 48 (50)		40
	40 x 32 (36)		28 x 40 (34)

Before completion of elongation.			After completion of elongation.		
		$\mu$			$\mu$
Average,	-	28	Average,	-	40 x 28 (34)
		37.2			24 x 28 (26)
Longitudinal wall 200 $\mu$ thick in interior of the stipe wall.		32	Longitudinal wall 200 $\mu$ thick in interior of stipe wall.		34 x 28 (31)
		32			36 x 30 (33)
		36			48
		40			44 x 40 (42)
		32			32 x 28 (30)
		24			48 x 40 (44)
		24			36
		32 x 28 (30)			40
		44 x 32 (38)		Average, -	38
		24			
Average,	-	31.2			
Longitudinal wall 240 $\mu$ thick in outer surface of stipe.		28	Longitudinal wall 260 $\mu$ thick, in outer surface of stipe and near cross wall.		44 x 40 (42)
		36 x 28 (32)			56 x 40 (48)
		24			40
		36			44 x 40 (42)
		34			40 x 32 (36)
		16 x 24 (20)			32 x 24 (28)
		34			44 x 32 (38)
		28 x 26 (27)			24
		36			60 x 28 (44)
		44 x 36 (40)			24 a
		16		Average, -	36.6
		20 x 28 (24)			
		28 x 10 (19)a			
Average,	-	28.5			

In this plant all the measurements of pseudoparenchyma made before the completion of elongation, give 31.3 $\mu$  as the average length of diameter of the cells in that stage. After completion of elongation, the corresponding average length is 37.9 $\mu$ . These results show an average increase of 21 per cent. in length of diameter of the cells of pseudoparenchyma during completion of elongation.

*Experiment 8.*—On October 14, a small egg just beginning

elongation at 8:00 A.M. had partially elongated to the length of 75<sup>mm</sup> at 10:00 A.M. The plant was then split longitudinally into halves. Sections were cut from the stipe of one of the halves as in the preceding experiments and measurements of the pseudoparenchyma were made. These measurements are given below in the column on the left. The other half of the plant was suspended in the supporting apparatus in a moist atmosphere until the completion of elongation of its receptaculum, when it measured 100<sup>mm</sup>. Sections were cut from its stipe at 3:00 P.M., October 15; the measurements of their pseudoparenchyma are given below in the column on the right.

Before completion of elongation.		After completion of elongation.	
	$\mu$		$\mu$
	28 x 40 (34) <sup>c</sup>		24 c
	28		24
Longitudinal wall	40 x 52 (46)	Longitudinal wall	36
next to central cavity	32	200 $\mu$ thick, next to	36 x 52 (44)
of stipe and in an	44 x 40 (42)	central cavity of	32
angle.	24	stipe.	36 x 32 (34)
	28		36 x 20 (28)
	32 x 24 (28)	Average, -	31.7
	28		
Average, -	32.2		
			44 c
		Longitudinal wall	20
		200 $\mu$ thick, next to	40 x 32 (36)
		central cavity of	32 x 40 (36)
		stipe and at a point	36
		near a cross wall.	40 x 36 (38)
			40 x 32 (36)
			28
		Average, -	34.2
	24		16
	30		28
Longitudinal wall	32 x 28 (30)	Longitudinal wall	32
160 $\mu$ thick in interior	32	160 $\mu$ thick in inte-	44
of stipe wall.	28 x 16 (22)	rior of stipe wall.	36

<sup>c</sup>In periphery of an angle.

Before completion of elongation.		After completion of elongation.	
	$\mu$		$\mu$
	26		44
	26		26
Average, -	27.1	Average, -	32.3
			28
		Longitudinal wall	44 x 40 (42)
		in interior of stipe	28
		wall at a point mid-	36 x 28 (32)
		way between cross	28 x 26 (27)
		walls.	28 x 24 (26)
		Average, -	30.7
	24		24
	24 x 20 (22)		28
Longitudinal wall	24 x 32 (28)	Longitudinal wall	28
in outer surface of	24 x 28 (26)	16 $\mu$ thick in outer	32 x 36 (34)
stipe.	24 x 32 (28)	surface of stipe.	28 x 24 (26)
	36 x 20 (28)		32 x 28 (30)
	28		32 x 24 (28)
	20 <i>a</i>		20 <i>a</i>
Average, -	25.5	Average, -	27.2

In this plant all the measurements of pseudoparenchyma from the partially elongated stipe give  $28.5\mu$  as the average length of diameter of the cells in that stage. After completion of elongation, the corresponding average length is  $31.2\mu$ . This is an increase of 9.5 per cent. in length of diameter of the cells of pseudoparenchyma during the later stages of elongation.

*Experiment 9* — To determine whether the longitudinal division of these plants into halves, as in *Experiments 6-8*, results in the development of the pseudoparenchyma to an abnormal size. The following measurements were made of pseudoparenchyma from the receptaculum of a vigorous plant whose elongation was normal and was completed before any incision was made into the stipe.

$\mu$	$\mu$
28	20 x 32 (26)
40	40 x 52 (46)

	$\mu$		$\mu$
Longitudinal wall.	48	Transverse parti-	28
	48 x 36 (42)	tion wall in interior	40 x 48 (44)
	40	stipe wall.	40 x 48 (44)
	28		40 x 36 (38)
	44	Average, -	37.7
Average, -	38.6		

Is has already been pointed out that these averages agree well with those of *Experiments 6* and *7*, in which equally vigorous plants were used.

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